FAUL 27 2005

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	21.Jul.05	THESIS

4. TITLE AND SUBTITLE
EFFECTIVENESS OF PERSONAL PROTECTIVE EQUIPMENT AND ISOLATION PRECAUTIONS IN PROTECTING HEALTHCARE WORKERS FROM ACQUIRING SEVERE ACUTE RESPIRATORY SYNDROME

5. FUNDING NUMBERS

6. AUTHOR(S)
MAJ NYQUIST ROBERT A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

8. PERFORMING ORGANIZATION REPORT NUMBER
CI04-1144

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

20050802 094

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS	15. NUMBER OF PAGES
	57
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

Effectiveness of Personal Protective Equipment and Isolation Precautions in Protecting Healthcare Workers from Acquiring Severe Acute Respiratory Syndrome

By

Robert A. Nyquist, D.V.M.

A Master's Paper submitted to the faculty of
the University of North Carolina at Chapel Hill
In partial fulfillment of the requirements for
the degree of Master of Public Health in
the Public Health Leadership Program.

Chapel Hill

2005

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Advisor

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Second Reader

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Date

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ABSTRACT

The outbreak of severe acute respiratory syndrome (SARS) was notable for its transmission within healthcare facilities, and in particular for infecting healthcare workers (HCWs) who provided direct patient care. This paper focuses on assessing the risk factors related to HCWs acquiring SARS and the effectiveness of infection control measures in protecting HCWs from disease transmission while caring for SARS infected patients. Risk factors associated with SARS transmission include contact with respiratory secretions, exposure to aerosol generating procedures, duration of exposure to SARS patients, duration of infection control training, and perceived inadequacy of personal protective equipment supply. Protective factors associated with SARS transmission include wearing of a mask and hand hygiene. In order to improve hospital preparedness for possible future disease outbreaks, efforts in enhancing infection control training must be a priority. Standardizing and improving the quality of research conducted in the face of a disease outbreak is another area deserving of attention.

INTRODUCTION

The severe acute respiratory syndrome (SARS) emerged as a new syndrome due to a novel human pathogen during November 2002 in Guangdong Province, China. In February 2003, a physician who had been treating cases of pneumonia in this southern province of China traveled to Hong Kong where he subsequently became ill. As a result of a one-day hotel stay in Hong Kong, ten individuals who stayed in the same hotel became infected with the severe acute respiratory syndrome-associated coronavirus (SARS-CoV) despite having no reported direct contact with the doctor. The subsequent travel of these infected hotel guests was responsible for the transport of SARS to five other countries and marked the beginning of the global outbreak.[1]

The World Health Organization (WHO) issued the first global alert pertaining to SARS on March 12, 2003.[2] This announcement described the outbreak of a severe form of atypical pneumonia occurring in Vietnam, Hong Kong, and Guangdong Province, China. A notable item of concern was that this severe respiratory illness had spread to a high number of healthcare workers (HCWs) in two of the three locations, and those at highest risk appeared to be staff providing direct patient care. Due to the unknown cause of the illness and the high incidence among HCWs, the WHO recommended isolation and barrier nursing techniques for treating patients with atypical pneumonia.

The last case of SARS associated with this outbreak was reported in July 2003. The Figure in Appendix 1 shows the total number of SARS cases and the number of infected HCWs for the top five affected geographical areas. Over the

course of the outbreak there were 8,096 cases reported in 26 countries resulting in 774 deaths. HCWs accounted for 1,706 of these reported cases, or roughly 20% of the cases worldwide.[3] Moreover, three countries reported greater than 40% of all SARS cases involved HCWs. Visitors and other patients also acquired SARS while in healthcare facilities. In Toronto, Canada and Singapore, >70% of all probable SARS patients were exposed in the healthcare setting.[4,5]

Several confirmed cases of SARS have occurred since the end of the outbreak in July, 2003. Separate SARS cases linked to laboratory acquisition occurred in Singapore and Taiwan during the fall of 2003, however neither case resulted in further transmission.[6] In December, 2003 the first naturally acquired case of SARS since the disease was contained was reported in Guangdong Province, China.[7] While authorities quickly quarantined 81 of the patient's contacts, three more cases were reported.[6] Finally, in late March and mid-April, 2004 two researchers at the National Institute of Virology in Beijing, China developed SARS. One of these cases was subsequently linked to seven other SARS patients, of which three were exposed in the healthcare setting.[8] As neither of the two researchers had conducted experiments using live SARS-CoV, lapses in biosafety procedures at the Institute were considered the most likely source of the infection.[9] As of June 1, 2005 additional cases of SARS have not been reported to the WHO since 2004.

Epidemiology of SARS

During the outbreak, the primary mode of SARS transmission appeared to occur via direct mucous membrane contact with respiratory droplets.[10-13] These

respiratory droplets were generated when a SARS patient talked, coughed, or sneezed. Reports have also suggested alternate modes of SARS transmission through contact with fomites[14-17] or opportunistic airborne spread.[17-20] Within healthcare settings, notable exceptions to the primary route of exposure occurred principally through aerosol generating procedures[21-23] and so called super-spreaders[5] or super-spreading events.[24] Examples of aerosol generating procedures included nasopharyngeal aspiration, bronchoscopy, endotracheal intubation, airway suctioning, cardiopulmonary resuscitation, and non-invasive positive pressure ventilation. An illustration of an apparent super-spreader was an ill hospital laundry attendant in Taiwan who continued working in spite of worsening symptoms. Ultimately this one worker was responsible for at least 137 probable SARS cases, including 45 HCWs.[25]

The basic reproduction number (R_0) of an infection gives a measure of how well an epidemic spreads in a susceptible population in the absence of control measures.[26] R_0 is defined as the average number of secondary cases generated by one primary case in a susceptible population. Studies of the transmission dynamics of SARS have estimated that the R_0 is 2.2-3.7.[26,27] This is consistent with a disease spread by direct contact or large respiratory droplets, as opposed to aerosol transmission.[12] R_0 does not need to be zero in order to stop an outbreak, but merely reduced and maintained below 1.

Measurement of viral load in nasopharyngeal aspirates taken from SARS patients indicates a significant rise after day 6. Peak virus excretion from the respiratory tract occurs at about day 10 or 11 of illness and then declines

quickly.[28,29] Viral shedding in stool appears to peak between day 9 to 14 of illness and then gradually declines.[28,29] Also significant was the finding that viral load in stool is much higher than that in nasopharyngeal aspirates.[29] These findings suggest that patients are most infectious during the second week of illness, which is when many of them were hospitalized. In addition, direct or indirect contact with stool may serve as a significant source of exposure.

SARS-CoV has been shown to survive outside of a human host for several days. The virus is stable in stool and urine at room temperature for at least 1-2 days. It was also shown that SARS-CoV is stable for up to 4 days in stool from patients with diarrhea, due to higher pH as compared with normal stool.[30] Additionally, the virus has been isolated from a dry plastic surface after 6 days[31] and after 4 days on a glass slide.[12] As a result, contaminated objects in the environment may act as inanimate carriers of SARS-Cov for several days potentially leading to cross-transmission via indirect contact.

Due to a lack of distinct clinical features separating SARS from other community-acquired respiratory infections, nosocomial spread within healthcare settings was the principal means of disease amplification early in the outbreak.[32,33] Atypical case presentations were also problematic and may have resulted in a more relaxed use of personal protective equipment (PPE) by HCWs involved with patient care.[14] Further complicating the issue of SARS transmission was whether or not asymptomatic infections were possible. Several large seroepidemiologic studies of HCWs conducted since the end of the SARS outbreak revealed that inapparent infection with SARS was uncommon.[34-37]

In response to this new disease, SARS infection control guidelines were developed by numerous health agencies (WHO,[38] Centers for Disease Control and Prevention [CDC],[39] Health Canada,[40] and others). Control measures implemented within healthcare facilities included patient screening and isolation, use of PPE by HCWs, and an emphasis on hand hygiene. Ultimately, the employment of infection control measures in healthcare settings, along with contact tracing and quarantine in the community, proved effective in bringing about an end to the SARS outbreak.

Much has been learned about SARS during and since the outbreak, but to date no systematic review has been published evaluating the risk factors for infection of HCWs or the effectiveness of preventive measures taken in healthcare facilities in halting transmission. While it is true that the actions taken during the outbreak were effective in interrupting SARS transmission, they were not without consequence in terms of direct and indirect costs,[41] impairment with patient care,[42] and psychological impact.[43,44] With ongoing concern over the potential for emergence of a new human pathogen or another influenza pandemic, efforts in assessing the infection control response to SARS in healthcare settings will benefit preparedness for any future outbreaks. The remainder of this paper focuses on assessing the risk factors related to HCWs acquiring SARS and the effectiveness of infection control measures in protecting HCWs from disease transmission while caring for SARS infected patients.

METHODS

To identify relevant articles, the MEDLINE database was searched from November 2002 through May 2005 by combining the Medical Subject Heading *severe acute respiratory syndrome* with *disease transmission, patient-to-professional* or *protective devices* (as well as *masks or gloves or gowns or goggles*) or *infection control* or *health personnel*. Additional search strategies involved hand searching bibliographies, and a journal hand search for the last twelve months of *Infection Control and Hospital Epidemiology* and *Clinical Infectious Diseases*.

Case-control and cohort studies conducted in hospital settings that examined the risk factors for HCWs acquiring SARS from infected patients, or determined protective factors for infection control practices utilized by HCWs while caring for SARS patients were reviewed. To avoid the possibility of unrecognized community acquired SARS transmission, studies had to include ≥ 3 infected HCWs who had cared for at least one confirmed SARS source patient. Articles had to report on original studies. Reviews, editorials, commentaries, case series reports, non English articles, and articles on dentistry were excluded from consideration.

The titles and abstracts of the articles identified by the literature search were reviewed and articles were excluded if they failed to meet the eligibility criteria. When it was not possible to determine if the eligibility criteria were met based upon the abstract alone, articles were carried forward and the full article was reviewed to determine inclusion or exclusion.

Articles were then abstracted and the relevant information from each article was recorded into evidence tables. Based on the evidence presented within the article, an assessment was made as to the internal and external validity. Internal validity of the two types of studies found in this review was based upon a determination of the potential for selection bias, information bias, and confounding present within the study. External validity was evaluated by the ability to generalize the findings of the study to a population of healthcare workers caring for patients in a hospital setting, within the limits of the study's internal validity. Whenever possible, the clinical importance of a study's findings is discussed as it relates to protection of HCWs from SARS transmission.

RESULTS

Risk Factors Associated with SARS Transmission

The risk factors associated with SARS transmission from patients to HCWs were evaluated in five hospital based studies.[21,22,45-47] The factors examined include time and proximity to a SARS patient, contact with respiratory secretions, present during aerosol generating procedures, and infection control training. The studies differed in the number of SARS patients treated, the duration of exposure, and the recognition by HCWs that a patient in fact had SARS. The studies are described below and significant findings are summarized in Table 1 in Appendix 1. Evidence tables for these studies are in Appendix 2.

Proximity and Duration of Exposure to SARS Patients

Scales and colleagues[45] evaluated the risk factors associated with the development of 7 SARS cases (6 probable, 1 suspected)[48,49] among a cohort of 69

HCWs who were exposed to an undiagnosed SARS patient during a 31 hour stay in an intensive-care unit (ICU). These 69 HCWs had entered the patient's room or had been in the ICU for ≥4 hours during the patient's stay. SARS developed in 6 of 31 HCWs who had entered the patient's room, and all six HCWs reported contact with the patient's mucous membranes or respiratory secretions while performing a procedure. PPE used among the six HCWs ranged from N-95 mask, gown, and gloves, to inconsistent PPE use or no PPE. The odds ratio (OR) for acquiring SARS when the HCW spent ≥31 minutes in the patient's room was 12.9 (95% confidence interval [CI], 1.27 to 131). When ≥4 hours were spent in the patient's room the OR for acquiring SARS was 24.0 (95% CI, 1.85 to 311).

SARS developed in 1 of 38 HCWs who had not entered the patient's room. This nurse was present in the ICU for almost 19 hours during the patient's stay. No conclusive evidence of exposure was available for this HCW, and there was no recognized exposure to any other persons known to have SARS. This case suggests possible airborne transmission or indirect person-to-person transmission.

Limitations of this study include the small sample size and the lack of confirmatory serological testing among the 7 HCWs diagnosed with SARS. Also problematic was the inadequate reporting of demographic characteristics of the cohort. One of the potential strengths of this study was the defined period of exposure to just one SARS patient in a confined hospital unit.

Exposure to Respiratory Secretions

Teleman and associates[46] investigated the factors that resulted in 44 laboratory confirmed cases of SARS in HCWs employed at Singapore's designated SARS referral treatment center. This nosocomial outbreak involving HCWs was linked to three source cases that were not initially diagnosed as having SARS. As a result of delayed recognition of SARS, these three patients were treated in general hospital wards and only placed in isolation anywhere from 3-8 days after admission. Over the course of this hospital based outbreak, there was a gradual escalation in PPE requirements. Initially, HCWs only employed N95 masks when caring for the first recognized SARS case. By the end of the second week PPE against contact, droplet, and respiratory transmission were implemented in SARS screening and treatment areas. Finally at the beginning of week 3, N95 masks were required when treating any patient in the hospital. While PPE requirements continued to increase for several more weeks, there was no further nosocomial transmission after the beginning of week 3. In multivariate analysis of factors associated with transmission of SARS to HCWs the adjusted OR for contact with respiratory secretions was 21.8 (95% CI, 1.7 to 274.8), controlling for gender, ethnicity, and use of N95 mask, gloves, and gown. Risk factors such as proximity, patient contact, duration of exposure, and performance of aerosol generating procedures were not shown to be significant in univariate analysis.

Controls for this study were selected from a pool of healthy HCWs who reported being within close proximity (1 meter) to probable SARS patients during

the same time period. The reported demographic characteristics of the case and control groups were similar except for a higher proportion of ethnic Chinese than non-Chinese among the cases. In a multivariate analysis, after adjusting for PPE, handwashing, and contact with respiratory secretions, the ethnicity of HCWs was no longer significant.

Limitations of the study include small sample size, incomplete exposure histories, HCWs caring for more than one SARS patient, recall bias during a stressful period, and potential differences between actual and reported use of PPE. Variation in stage of infection for each source patient, which could have affected viral load and subsequently viral shedding, was also not addressed.

Present During Aerosol Generating Procedures

Four studies[21,22,45,46] included data on HCW exposure to aerosol generating procedures during care of SARS patients. One of the four studies focused primarily on aerosol generating procedures, while the other three included this among other factors analyzed.

Fowler and colleagues[22] reviewed the factors involved in 10 probable cases of SARS that developed among a cohort of 122 HCWs who were exposed to 7 SARS patients treated with various modes of ventilator support. All patients were treated in negative-pressure isolation rooms, and all HCWs wore gloves, gowns, N95 or PCM2000 masks, and hairnets. Use of eye or face shields was variable. The relative risk (RR) for physicians performing endotracheal intubation was 3.82 (95% CI, 0.23 to 62.24), which was not statistically significant. In contrast, the RR for nurses who assisted with intubation was 21.38

(95% CI, 4.89 to 93.37). The risk of developing SARS for nurses who cared for patients with high-airflow, noninvasive positive-pressure ventilation (NPPV) or high-frequency oscillatory (HFO) ventilation, as compared with nurses who cared for patients treated with conventional ventilation was 2.33 (95% CI, 0.25 to 21.76) and 0.74 (95% CI, 0.11 to 4.92) respectively; both of which were not statistically significant.

Limitations of this study include the small sample size, especially for physicians performing endotracheal intubation, and lack of laboratory confirmation of the source patients. Also, there was very limited demographic data available as to the composition of the cohort and there was no mention of how exposure data was collected.

Loeb and associates[21] evaluated the risk factors associated with 8 cases (4 probable and 4 suspected based upon the WHO clinical case definition; all laboratory confirmed) of SARS among 32 HCWs who cared for 3 laboratory confirmed SARS source patients. All 32 HCWs had entered a SARS patient's room at least once. The type and consistency of PPE use by the 32 HCWs was reported as variable. The RR for suctioning before intubation of SARS patients was 4.20 (95% CI, 1.58 to 11.14). The RR for assisting with intubation of SARS patients was 4.20 (95% CI, 1.58 to 11.14). The RR for manipulating an oxygen mask was 9.0 (95% CI, 1.25 to 64.9). No multivariate analysis was performed.

Limitations of this study include small sample size and recall bias. A potential strength of this study was the verification of the information provided by

the nurses through comparison with the clinical notation recorded in the medical record of each SARS patient.

Scales et al[45] reported 3 out of 5 HCWs present during intubation of a SARS patient developed SARS. Also, the OR for HCWs being present in the patient's room for >31 minutes during the administration of NPPV was 105 (95% CI, 3 to 3,035). In contrast, Teleman[46] reported no statistical differences between cases and controls in univariate analysis of assisting with intubation, suctioning of body fluids, or administering oxygen.

Infection Control Training

Lau and colleagues[47] investigated the risk factors associated with 77 probable and suspected SARS cases involving HCWs from five hospitals in Hong Kong between March and May, 2003. Each HCW with SARS was matched with two healthy controls who worked in the same job position, on the same ward, and in proximity (not defined) to a SARS patient. During this same time period, there were 453 confirmed SARS cases treated in the five hospitals. As all HCWs were required to wear protective masks (either N95 respirator or surgical mask) during this time period, breakthrough transmission was assumed to be responsible for all cases of SARS among these HCWs. Factors reviewed in this study included exposure (both within the healthcare setting and socially), PPE, and infection control training.

Unadjusted results suggested that the duration of infection control training (<2 hours versus ≥2 hours) was positively associated with understanding of infection control practices, and that failure to understand infection control

measures resulted in higher risk of SARS infection, OR 3.14 (95% CI, 1.35 to 7.73). After controlling for exposure and PPE variables, the adjusted OR for SARS infection control training <2 hours or no training was 13.6 (95% CI, 1.24 to 27.50).

There were several limitations noted in this study. Job category was the only demographic or background data provided on the sample group. Thus it was not possible to evaluate the comparability of the case and control groups. Recall bias may have also affected the study results, as there was no way to measure actual compliance with infection control training attendance or duration. HCWs may have had a tendency to over report training and PPE use when responding to the questionnaires in order to avoid potential repercussions. Strengths of the study include a relatively large sample size and the controlling for exposure (healthcare setting versus social) in the multivariate analysis.

Protective Factors

The protective factors associated with a lack of SARS transmission from patient to HCW were evaluated in five hospital based studies.[21,45-47,50] The protective effect of masks, gloves, gowns, perception of PPE supply, and hand hygiene were examined. The studies are described below and significant findings are summarized in Table 2 in Appendix 1. Evidence tables for these studies are in Appendix 2.

Use of Personal Protective Equipment

Five studies[21,45-47,50] reported on the risk factors associated with use of PPE by HCWs during direct contact with SARS patients. All five studies

evaluated HCW use of PPE along with other factors that may have affected the risk of acquiring SARS from infected patients.

Seto and associates[50] evaluated the protective effect of masks, gloves, gowns, and handwashing associated with 13 laboratory confirmed SARS cases involving HCWs from five hospitals in Hong Kong occurring over ten days in March, 2003. 241 non-infected HCWs who had similar exposure to 11 SARS patients were used as controls. Exposure was defined as coming within 3 feet of an index patient, while also having no exposure to SARS cases outside of the hospital. Use of PPE was classified as yes, most of the time, and no. For analysis, responses for yes and most of the time were grouped together. No HCW who reported employing all four precautions became infected, whereas all infected HCWs had omitted at least one of the protective measures. In multivariate analysis of the four factors measured, only use of a mask was found to be significant. The use of a mask (N95, surgical, or paper) had a protective OR of 13 (95% CI, 3 to 60), adjusting for the use of gloves, gown and handwashing. When use of each type of mask was compared with the use of no mask, only N95 and surgical masks were shown to significantly reduce the risk of SARS infection.

There were several limitations noted in the analysis of this study. The differences in the demographic characteristics between the case and control groups were not presented. Also, the possible differences in HCW-patient exposure intensity between the case and control groups were not fully evaluated. One HCW infected with SARS was excluded from the case group due to a lack of known exposure to one of the 11 index cases, and was thus listed as community

acquired. Finally, the authors excluded from consideration a 'large' nosocomial outbreak at a sixth Hong Kong hospital that was associated with an aerosol generating procedure. Although this omission was in line with their study question assessing the effectiveness of droplet precautions for prevention of SARS in HCWs, it may have also affected the external validity of the study.

Teleman and associates[46] evaluated the same four transmission precautions as Seto et al in their study of HCWs in Singapore. The OR for a HCW acquiring SARS while wearing an N95 mask was 0.1 (95% CI, 0.02 to 0.9), adjusting for use of gloves, gown, and hand hygiene. Of note in this study is the fact that lengthy aerosol generating procedures were not performed on any of the 3 index cases, and that there was no significant difference between cases and controls for performing short duration aerosol generating procedures. Use of gloves and gowns were not significantly associated with transmission prevention during contact with a SARS patient.

Scales and colleagues[45] reported an OR of 0.08 (95% CI, 0.01 to 1.11) for use of gloves by HCWs when in direct contact with a SARS patient, however this result was not statistically significant. No OR was reported for use of gowns or masks.

Loeb and associates[21] evaluated the ability of masks, gloves and gowns to prevent the transmission of SARS to HCWs. The RR for acquiring SARS when HCWs consistently wore a mask (N95 or surgical) was 0.23 (95% CI, 0.07 to 0.78). When consistent use of a N95 mask was compared with inconsistent use a mask, the RR for infection was 0.22 (95% CI, 0.05 to 0.93). When consistent use

of a surgical mask was compared with inconsistent use of a mask, the RR was 0.45 (95% CI, 0.07 to 2.71). Comparing consistent use of N95 mask versus consistent use of a surgical mask, the RR was 0.5 (95% CI, 0.06 to 4.23). The RR for use of both gowns and gloves was not statistically significant. No multivariate analysis was performed.

Lau and colleagues[47] reported on use of PPE, perceived inadequacy of PPE supply, and problems with PPE use. Univariate analysis for all types of PPE use was stratified into three settings based on history of HCW contact with patients: direct contact with SARS patient; direct contact with patients in general; and no patient contact. The OR was reported as the risk from inconsistent use of different types of PPE. Due to the fact that nearly every HCW reported wearing either a N95 or surgical mask in all three settings, the OR for inconsistent use of any type of mask was not statistically significant. The unadjusted OR for inconsistent use of goggles when in direct contact with SARS patients was 6.41 (95% CI, 2.49 to 19.49). The unadjusted OR for inconsistent use of a gown when in direct contact with a SARS patient was 8.85 (95% CI, 2.46 to 48.28). The unadjusted OR for inconsistent use of gloves when in direct contact with SARS patients was 20.54 (95% CI, 2.96 to 887.72). In multivariate analysis, inconsistent use of more than one type of PPE when having direct contact with SARS patients had an adjusted OR of 5.06 (95% CI, 1.91 to 598.92).

During the time period of the study there was a perceived or actual shortage of the various types of PPE used by HCWs to protect against SARS transmission. The actual supply levels of the various PPE items were not verified

by the study. The adjusted OR for perceived inadequacy of PPE supply was 4.27 (95% CI, 1.66 to 12.54).

Hand hygiene

Three studies[46,47,50] reported results on the effects of hand hygiene on preventing SARS transmission to HCWs. Seto and associates[50] reported a protective OR for handwashing of 5 (95% CI, 1 to 19), however handwashing was not found to be statistically significant in multivariate analysis and was dropped from the logistic regression model. In contrast, multivariate analysis by Teleman et al[46] found that handwashing after each patient had an adjusted OR for SARS transmission of 0.07 (95% CI, 0.008 to 0.7). Lau and colleagues[47] reported that >97% of both cases and controls practiced good hand hygiene after contact with SARS patients or patients in general, and thus the OR difference between the case and control group was not statistically significant. However, the OR for inconsistent hand hygiene when there was no patient contact was reported as 6.38 (95% CI, 1.64 to 36.17).

DISCUSSION

Factors associated with an increased risk of SARS transmission from infected patient to HCWs include contact with respiratory secretions, exposure to aerosol generating procedures, duration of exposure to SARS patients, duration of infection control training, and perceived inadequacy of PPE supply. Protective factors associated with a reduced risk of SARS transmission to HCWs include wear of a mask and hand hygiene.

The available evidence supports respiratory droplet transmission as a primary mode for SARS to spread from infected patient to HCW in the healthcare setting. The role of contact transmission remains less clearly defined. While hand hygiene appeared to reduce the risk of SARS infection, the use of gloves failed to significantly decrease the risk of transmission to HCWs caring for SARS infected patients. Patient care activities associated with aerosol generating procedures represent a significant risk to HCWs caring for SARS patients. However, the evidence reviewed does not support widespread aerosolization of SARS-CoV in hospital settings.

Scales et al showed evidence of a dose-response relationship with risk of SARS transmission to HCWs increasing as time spent in proximity to an infected patient increased. On the other hand, the results of Teleman and colleagues did not support this relationship.

The importance of infection control training was highlighted by Lau and associates. Decreased length of time spent in infection control training was associated with decreased understanding of personal protective measures and significantly related to an increased risk of SARS transmission. The reduced risk of SARS transmission conferred by hand hygiene also attests to the importance of infection control training in the healthcare setting.

Wearing any type of mask while caring for SARS infected patients reduced the risk of transmission to HCWs by as much as twelve times, and was the only PPE item shown to be statistically significant in protecting HCWs from infection. A side-by-side comparison of N95 versus surgical mask by Loeb et al

favored N95 masks, but this difference was not statistically significant. In resource poor countries surgical masks may be recommended. However, if patient factors (persistent coughing, high viral shedding) or aerosol generating procedures are being performed then the use of an N95 respirator should be encouraged.[51] When possible an N95 respirator should be used because of improved filtering efficacy, in the absence of demonstrated clinical/epidemiologic superiority. The use of a powered air purifying respirator (PAPR) should be considered during aerosol generating procedures, although again neither clinical nor epidemiologic studies evaluated the effectiveness of this means of respiratory protection.

During the initial response to the global SARS outbreak, infection control guidelines and PPE requirements were in a perpetual state of refinement. In the United States, recommended infection control practices quickly evolved to include placement of SARS patients in a room meeting airborne protection requirements (i.e., negative-pressure, direct out exhausted air, and >6 air-exchanges per hour), N95 or higher level of respiratory protection, gloves, gown, eye protection (goggles or face shield), and hand hygiene.[23,39] These published infection control guidelines represent the ideal. Out of necessity, treatment of SARS infected patients in other countries occasionally took place under less than optimal conditions due to failures in early recognition of the disease,[14,45,52] lack of properly designed isolation facilities,[53,54] or inadequate PPE supplies.[54,55]

The finding that inconsistent use of more than one type of PPE when having direct contact with a SARS patient significantly increased the risk of

SARS transmission is not surprising. All studies in this review measured PPE use as a dichotomous or categorical variable (i.e., "inconsistent use" or "most of the time"). Use of more precisely defined categories or quantitative measures might have allowed for a clearer understanding of the role of various types of PPE in preventing SARS transmission. However, to accomplish this type of data analysis requires a prospective data collection approach to ensure validity.

During the 2003 SARS outbreak, countries reported wide variation in the level of SARS transmission to HCWs. While China, Canada, and Singapore reported high numbers of HCWs infected, healthcare facilities in the United States reported no transmission to HCWs despite numerous unprotected exposures.[56] A survey of U.S. HCWs who reported known unprotected exposure to a SARS infected patient revealed the most likely neglected forms of PPE were gloves (39%), mask (44%), and eye protection (70%). Reasons suggested for the lack of SARS transmission to HCWs in the U.S. healthcare settings included the small number of SARS cases in the US (N=8), patients who were less infectious and a relative lack of high-risk patient procedures performed.[56]

Selected healthcare facilities[53] or wards[57] in other countries also reported zero SARS cases among HCWs. Among HCWs on the SARS ward in a Vietnam hospital, only 90% reported always wearing an N95 mask and HCWs reported using gloves only 76% of the time.[53] Proposed rationale for the lack of transmission were similar to those for U.S. facilities. In contrast, a pediatric ward in Hong Kong managed to prevent SARS transmission by employing a

conservative triage policy and enforcing the proper donning and removal of PPE by having a nurse monitor other HCWs.[57]

None of the studies included in this systematic review attempted to determine the proportion of HCWs who properly wore PPE or the significance of contact transmission during PPE removal. The proper donning and removal of PPE entails a methodical process and failure to adhere to the prescribed sequence for PPE removal can lead to exposure. Recommendations for putting on and removing PPE have been published,[57-59] and CDC guidelines are included at Appendix 3. However, it should be noted that none of these PPE donning and removal recommendations have been validated as to whether they actually reduce or prevent SARS transmission.

On the other end of the PPE use continuum are examples of HCWs acquiring SARS despite apparent adherence to infection control recommendations.[23,60,61] In an intensive care unit in Toronto, 9 HCWs exposed to a laboratory confirmed SARS patient developed suspected or probable SARS.[23] Infected HCWs reported wearing all recommended PPE each time they entered the patient's room. Several reasons were offered as to why full PPE apparently failed to prevent SARS transmission. First, HCWs had not been fit tested prior to wearing a PCM2000 duckbill mask, as is required in the United States. Secondly, the masks used were N95 equivalent that met Canadian public health recommendations, but were not National Institute for Occupational Safety and Health approved. Third, the patient had a nearly constant cough prior to intubation and was subsequently maintained on high-frequency oscillatory

ventilation for 7 days. The coughing, intubation, and ventilation may have generated aerosols leading to limited airborne spread for which the level of respiratory protection used did not prevent transmission. Finally, exposure may have occurred during PPE removal as HCWs did not have a clear understanding of how to remove PPE without contaminating themselves.[23]

Synthesizing the results of the reviewed studies with other published case reports leads to several conclusions. The primary mode of SARS transmission in healthcare settings involves respiratory droplets, while contact and opportunistic airborne transmission also occurred. Use of a mask by HCWs when caring for SARS patients provides significant protection against disease transmission. Furthermore, lapses in infection control policy, training, and individual use by HCWs contribute to an increased risk for SARS transmission.

Despite the modest efforts by researchers to characterize risk factors for transmission in the studies reviewed for this paper, gaps in our knowledge of SARS transmission persist. The actual roles of contact and airborne transmission within the healthcare setting remain indeterminate. Also, the wide confidence interval for each of the presented relative risks or odd ratios indicates the degree of uncertainty associated with the point estimate and small size of the study samples. Finally, the factors that contribute to certain patients being more infectious than others remains poorly defined.

The SARS outbreak represented a wake up call for the global healthcare community, as lapses in infection control practices significantly contributed to the nosocomial transmission of SARS. In order to improve hospital preparedness for

possible future disease outbreaks, efforts in enhancing infection control training must be a priority. Standardizing and improving the quality of research conducted in the face of a disease outbreak is another area deserving of attention.

Enhancing Hospital Infection Control

Based upon the best evidence available at the time, affected countries implemented infection control measures in hospitals and community settings that effectively brought about an end the SARS outbreak. To foster preparedness within healthcare settings for a return of SARS or the possible emergence of another communicable disease, it is necessary to evaluate the lessons learned from the 2003 SARS outbreak.

Routine infection control training must emphasize when, how and why to use PPE. Other aspects of infection control training include the proper sequence for removing PPE to avoid self contamination and the importance of performing hand hygiene, especially when leaving patient rooms.[17] An assessment of comprehension and a demonstration of task proficiency should be built into infection control training. Consistency of PPE use needs to be part of the everyday culture of care, and shortcuts that ignore PPE use for expediency should not be acceptable. The actions and emphasis placed on occupational health and safety by management can go a long way towards setting the tone for the safety climate within healthcare settings.[62,63]

During a recognized disease outbreak, time must be allotted for refresher training on infection control. Such training would convey what is known and what actions need to be taken by HCWs to reduce the risk of acquiring the current

disease threat. Proactive monitoring of infection control practices and PPE use by "sitters" or "buddy checks" needs to take place to ensure HCWs are complying with all recommendations.[38,57,60,64] Such monitoring would be especially important in high risk areas such as isolation rooms and critical care units. This would help to reinforce the importance of infection control measures and allow for on the spot corrections.

The rapid recognition and isolation of potentially infectious patients is a key aspect in minimizing disease transmission in the healthcare setting. With regards to SARS, this process is complicated by nonspecific initial symptoms,[32,33] atypical presentations,[14,65] and limited sensitivity and specificity of surveillance criteria.[66-68] To compensate for the lack of early definitive indicators of SARS, a conservative approach to triage[49,57,64,69] and initial isolation[39] of potentially infectious patients is often preferable to waiting until a confirmed diagnosis is made.

Implementation of universal respiratory hygiene and cough etiquette practices in healthcare facilities should decrease the risk of SARS transmission to HCWs from unrecognized patients, as well as facilitate control of nosocomial spread of other common respiratory pathogens.[69,70] Another aspect of infection control requiring consideration during an outbreak is to determine what procedures pose the greatest risk for disease transmission to HCWs. In the case of SARS, aerosol generating procedures such as intubation and nebulized medications posed a significant risk to HCWs for disease transmission. Once

recognized, task specific control measures should be established[60,71] and appropriate guidelines widely disseminated via electronic means.

The final aspect of infection control to address in the planning phase for an outbreak is how to actively conduct surveillance for additional cases within the healthcare setting. A system for monitoring patients in all wards for signs suggestive of infection is one component. The other is to monitor and exclude potentially exposed HCWs. During the SARS outbreak, daily symptom screening and temperature checks were employed to identify HCWS as early as possible and keep them from possibly exposing other HCWs or patients.[25,52,72,73] Dwosh and associates reported that SARS screening identified 3 of 10 HCWs when they arrived for work at a Toronto hospital.[73] Similarly, Gopalakrishna et al found fever surveillance rapidly identified potentially infected HCWs in SARS affected healthcare facilities in Singapore.[72]

Planning Future Studies

The quantitative data reviewed in this paper is based upon surveying less than 9% of the 1,700 HCWs who were infected with SARS. Researchers must do a better job in conducting studies of HCWs during outbreaks in order to increase our understanding of transmission risks associated with certain procedures and risk reduction provided by PPE.

Instead of reacting to the uncertainties of a novel disease outbreak with hastily conducted studies, planning and preparation must be undertaken ahead of the next disease outbreak. By establishing a template for collecting and analyzing data on transmission risk factors, researchers could potentially conduct

prospective cohort studies as the outbreak unfolded. This would increase the accuracy of exposure measurements and greatly minimize recall bias. Preplanning would also spur discussion on a standardized approach to evaluating exposure risk, which would allow for ready comparison of results between studies. An established set of demographic and background characteristics on study subjects would help recognize the potential for selection bias, which if found could possibly be controlled for by stratifying the groups on a given characteristic.

Nurses, physicians, administrative support, and housekeeping personnel represent the core components of the healthcare staff required to keep a hospital functioning. Unless we put a greater emphasis on ensuring these HCWs are protected from nosocomial disease transmission, we run the risk of not having this HCW pool available or willing to care for infected patients during future disease outbreaks. We need to make certain healthcare worker safety receives as much attention as patient safety within healthcare settings. Establishing a 'culture of infection control' and preplanning for future research efforts during an outbreak represent two ways for HCWs to gain the essential advantage over the next viral or bacterial adversary.

CITATIONS

1. Centers for Disease Control and Prevention. Update: outbreak of severe acute respiratory syndrome-worldwide, 2003. *MMWR Morb Mortal Wkly Rep.* 2003; 52:241-8.

2. World Health Organization. WHO issues a global alert about cases of atypical pneumonia, 12 March 2003. Available at: http://www.who.int/mediacentre/news/releases/2003/pr22/en/. Accessed June 15, 2005.

3. World Health Organization. Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003 (revised 31 December 2003). Available at: http://www.who.int/csr/sars/country/table2004_04_21/en/. Accessed June 15, 2005.

4. Svoboda T, Henry B, Shulman L, et al. Public health measure to control the spread of the severe acute respiratory syndrome during the outbreak in Toronto. *N Engl J Med.* 2004; 350:2352-61.

5. Centers for Disease Control and Prevention. Severe acute respiratory syndrome--Singapore, 2003. *MMWR Morb Mortal Wkly Rep.* 2003; 52:405-11.

6. World Health Organization. China reports additional SARS case - update 3, 28 April 2004. Available at: http://www.who.int/csr/don/2004_04_28/en/. Accessed June 15, 2005.

7. Cyranoski D. Swift response greets return of SARS in China. *Nature.* 2004; 427:89.

8. World Health Organization. China confirms SARS infection in another previously reported case; summary of cases to date - update 5, 30 April 2004. Available at: http://www.who.int/csr/don/2004_04_30/en/. Accessed June 15, 2005.

9. World Health Organization. China's latest SARS outbreak has been contained, but biosafety concerns remain – Update 7, 18 May 2004. Available at: http://www.who.int/csr/don/2004_05_18a/en/. Accessed June 15, 2005.

10. Peiris JS, Lai ST, Poon LL, et al. Coronavirus as a possible cause of severe acute respiratory syndrome. *Lancet.* 2003; 361:1319-25.

11. Poutanen SM, Low DE, Henry B, et al. Identification of severe acute respiratory syndrome in Canada. *N Engl J Med.* 2003; 348:1995-2005.

12. World Health Organization. Consensus document on the epidemiology of severe acute respiratory syndrome (SARS), 2003. Available at: http://www.who.int/csr/sars/en/WHOconsensus.pdf. Accessed June 15, 2005.

13. Wang WK, Chen SY, Liu IJ, et al. Detection of SARS-associated coronavirus in throat wash and saliva in early diagnosis. *Emerg Infect Dis.* 2004; 10:1213-9.

14. Chow KY, Lee CE, Ling ML, Heng DM, Yap SG. Outbreak of severe acute respiratory syndrome in a tertiary hospital in Singapore, linked to an index patient with atypical presentation: epidemiological study. *BMJ.* 2004; 328:195-9.

15. Chen YC, Huang LM, Chan CC, et al. SARS in hospital emergency room. *Emerg Infect Dis.* 2004; 10:782-8.

16. Dowell SF, Simmerman JM, Erdman DD, et al. Severe acute respiratory syndrome coronavirus on hospital surfaces. *Clin Infect Dis.* 2004; 39:652-7.

17. Booth TF, Kournikakis B, Bastien N, et al. Detection of airborne severe acute respiratory syndrome (SARS) coronavirus and environmental contamination in SARS outbreak units. *J Infect Dis*. 2005; 191:1472-7.

18. Olsen SJ, Chang HL, Cheung TY, et al. Transmission of the severe acute respiratory syndrome on aircraft. *N Engl J Med*. 2003; 349:2416-22.

19. Yu IT, Li Y, Wong TW, et al. Evidence of airborne transmission of the severe acute respiratory syndrome virus. *N Engl J Med*. 2004; 350:1731-9.

20. Yu IT, Wong TW, Chiu YL, Lee N, Li Y. Temporal-spatial analysis of severe acute respiratory syndrome among hospital inpatients. *Clin Infect Dis*. 2005; 40:1237-43.

21. Loeb M, McGeer A, Henry B, et al. SARS among critical care nurses, Toronto. *Emerg Infect Dis*. 2004; 10:251-5.

22. Fowler RA, Guest CB, Lapinsky SE, et al. Transmission of severe acute respiratory syndrome during intubation and mechanical ventilation. *Am J Respir Crit Care Med*. 2004; 169:1198-1202.

23. Centers for Disease Control and Prevention. Cluster of severe acute respiratory syndrome cases among protected health-care workers--Toronto, Canada, April 2003. *MMWR Morb Mortal Wkly Rep*. 2003; 52:433-6.

24. Shen Z, Ning F, Zhou W, et al. Superspreading SARS events, Beijing, 2003. *Emerg Infect Dis*. 2004; 10:256-60.

25. McDonald LC, Simor AE, Su IJ, et al. SARS in healthcare facilities, Toronto and Taiwan. *Emerg Infect Dis*. 2004; 10:777-81.

26. Lipsitch M, Cohen T, Cooper B, et al. Transmission dynamics and control of severe acute respiratory syndrome. *Science.* 2003; 300:1966-70.

27. Riley S, Fraser C, Donnelly CA, et al. Transmission dynamics of the etiological agent of SARS in Hong Kong: impact of public health interventions. *Science.* 2003; 300:1961-6.

28. Peiris JS, Chu CM, Cheng VC, et al. Clinical progression and viral load in a community outbreak of coronavirus-associated SARS pneumonia: a prospective study. *Lancet.* 2003; 361:1767-72.

29. Cheng PK, Wong DA, Tong LK, et al. Viral shedding patterns of coronavirus in patients with probable severe acute respiratory syndrome. *Lancet.* 2004; 363:1699-1700.

30. World Health Organization. First data on stability and resistance of SARS coronavirus compiled by members of WHO laboratory network, 2003. Available at: http://www.who.int/csr/sars/survival_2003_05_04/en/index.html. Accessed June 15, 2005.

31. Rabenau HF, Cinatl J, Morgenstern B, Bauer G, Preiser W, Doerr HW. Stability and inactivation of SARS coronavirus. *Med Microbiol Immunol.* 2005; 194:1-6.

32. Jernigan JA, Low DE, Helfand RF. Combining clinical and epidemiological features for early recognition of SARS. *Emerg Infect Dis.* 2004; 10:327-33.

33. Kahn K, Muennig P, Gardam M, Zivin JG. Managing febrile respiratory illnesses during a hypothetical SARS outbreak. *Emerg Infect Dis.* 2005; 11:191-200.

34. Chan PK, Ip M, Ng KC, et al. Severe acute respiratory syndrome-associated coronavirus infection. *Emerg Infect Dis*. 2003; 9:1453-4.

35. Ho KY, Singh KS, Habib AG, et al. Mild illness associated with severe acute respiratory syndrome coronavirus infection: lessons from a prospective seroepidemiologic study of health-care workers in a teaching hospital in Singapore. *J Infect Dis*. 2004; 189:642-47.

36. Leung GM, Chung PH, Tsang T, et al. SARS-CoV antibody prevalence in all Hong Kong patient contacts. *Emerg Infect Dis*. 2004; 10:1653-6.

37. Chen WQ, Lu CY, Wong TW, et al. Anti-SARS-CoV immunoglobulin G in healthcare workers, Guangzhou, China. *Emerg Infect Dis*. 2005; 11:89-94.

38. World Health Organization. Hospital infection control guidance for severe acute respiratory syndrome (SARS), 24 April 2003. Available at: http://www.who.int/csr/sars/infectioncontrol/en/. Accessed June 15, 2005.

39. Centers for Disease Control and Prevention. Supplement I: infection control in healthcare, home, and community settings, 8 January 2004. Available at: http://www.cdc.gov/ncidod/sars/guidance/i/pdf/i.pdf. Accessed June 15, 2005.

40. Health Canada. Infection control guidance if there is a SARS outbreak anywhere in the world, when an individual presents to a health care institution with a respiratory infection, 17 December 2003. Available at: http://www.phac-aspc.gc.ca/sars-sras/pdf/sars-icg-outbreakworld_e.pdf. Accessed June 15, 2005.

41. Achonu C, Laporte A, Gardam MA. The financial impact of controlling a respiratory virus outbreak in a teaching hospital: lessons learned from SARS. *Can J Public Health*. 2005 ;96:52-4.

42. Chang HJ, Huang N, Lee CH, Hsu YJ, Hsieh CJ, Chou YJ. The impact of the SARS epidemic on the utilization of medical services: SARS and the fear of SARS. *Am J Public Health.* 2004; 94:562-4.

43. Maunder R, Hunter J, Vincent L, et al. The immediate psychological and occupational impact of the 2003 SARS outbreak in a teaching hospital. *CMAJ.* 2003; 168:1245-51.

44. Hawryluck L, Gold WL, Robinson S, Pogorski S, Galea S, Styra R. SARS control and psychological effects of quarantine, Toronto, Canada. *Emerg Infect Dis.* 2004; 10:1206-12.

45. Scales DC, Green K, Chan AK, et al. Illness in intensive care staff after brief exposure to severe acute respiratory syndrome. *Emerg Infect Dis.* 2003; 9:1205-10.

46. Teleman MD, Boudville IC, Heng BH, Zhu D, Leo YS. Factors associated with transmission of severe acute respiratory syndrome among health-care workers in Singapore. *Epidemiol Infect.* 2004; 132:797-803.

47. Lau JT, Fung KS, Wong TW, et al. SARS transmission among hospital workers in Hong Kong. *Emerg Infect Dis.* 2004; 10:280-6.

48. World Health Organization. WHO guidelines for the global surveillance of severe acute respiratory syndrome (SARS), Updated recommendations, October 2004. Available at: http://www.who.int/csr/resources/publications/en/WHO_CDS_CSR_ARO_2004_1.pdf. Accessed June 15, 2005.

49. Centers for Disease Control and Prevention. Supplement B: SARS surveillance, 8 January 2004. Available at: http://www.cdc.gov/ncidod/sars/guidance/B/pdf/b.pdf. Accessed June 15, 2005.

50. Seto WH, Tsang D, Yung RW, et al. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). *Lancet.* 2003; 361:1519-20.

51. Derrick JL, Gomersall CD. Protecting healthcare staff from severe acute respiratory syndrome: filtration capacity of multiple surgical masks. *J Hosp Infect.* 2005; 59:365-8.

52. Gopalakrishna G, Choo P, Leo YS, et al. SARS transmission and hospital containment. *Emerg Infect Dis.* 2004; 10:395-400.

53. Ha LD, Bloom SA, Hien NQ, et al. Lack of SARS transmission among public hospital workers, Vietnam. *Emerg Infect Dis.* 2004; 10:265-8.

54. Lee NE, Siriarayapon P, Tappero J, et al. Infection control practices for SARS in Lao People's Democratic Republic, Taiwan, and Thailand: experience from mobile SARS containment teams, 2003. *Am J Infect Control.* 2004; 32:377-83.

55. Ho AS, Sung JJ, Chan-Yeung M. An outbreak of severe acute respiratory syndrome among hospital workers in a community hospital in Hong Kong. *Ann Intern Med.* 2003; 139:564-7.

56. Park BJ, Peck AJ, Kuehnert MJ, et al. Lack of SARS transmission among healthcare workers, United States. *Emerg Infect Dis.* 2004; 10:244-8.

57. Leung TF, Ng PC, Cheng FW, et al. Infection control for SARS in a tertiary paediatric centre in Hong Kong. *J Hosp Infect.* 2004; 56:215-22.

58. Loutfy MR, Wallington T, Rutledge T, et al. Hospital preparedness and SARS. *Emerg Infect Dis.* 2004; 10:771-6.

59. Centers for Disease Control and Prevention. Poster: sequence for donning and removing personal protective equipment (PPE), May 7, 2004. Available at: http://www.cdc.gov/ncidod/sars/pdf/ppeposter148.pdf. Accessed June 15, 2005.

60. Christian MD, Loutfy M, McDonald LC, et al. Possible SARS coronavirus transmission during cardiopulmonary resuscitation. *Emerg Infect Dis.* 2004; 10:287-93.

61. Chen YC, Chen PJ, Chang SC, et al. Infection control and SARS transmission among healthcare workers, Taiwan. *Emerg Infect Dis.* 2004; 10:895-8.

62. Yassi A, Moore D, FitzGerald JM, et al. Research gaps in protecting healthcare workers from SARS and other respiratory pathogens: an interdisciplinary, multi-stakeholder, evidence-based approach. *J Occup Environ Med.* 2005; 47:41-50.

63. Moore D, Gamage B, Bryce E, Copes R, Yassi A; The BC Interdisciplinary Respiratory Protection Study Group. Protecting health care workers from SARS and other respiratory pathogens: organizational and individual factors that affect adherence to infection control guidelines. *Am J Infect Control.* 2005; 33:88-96.

64. Weber DJ, Rutala WA. Lessons learned from managing a case of SARS. *Infect Dis Soc Amer News.* 2003; 13:8-9.

65. Fisher DA, Lim TK, Lim YT, Singh KS, Tambyah PA. Atypical presentations of SARS. *Lancet.* 2003; 361:1740.

66. Chong WC, Tham KY, Goh HK, Seow E. Presentation of severe respiratory syndrome (SARS) patients in a screening centre. *Singapore Med J.* 2005; 46:161-4.

67. Escudero IH, Chen MI, Leo YS. Surveillance of severe acute respiratory syndrome (SARS) in the post-outbreak period. *Singapore Med J.* 2005; 46:165-71.

68. Muller MP, Tomlinson G, Marrie TJ, et al. Can routine laboratory tests discriminate between severe acute respiratory syndrome and other causes of community-acquired pneumonia? *Clin Infect Dis.* 2005; 40:1079-86.

69. Srinivasan A, McDonald LC, Jernigan D, et al. Foundations of the severe acute respiratory syndrome preparedness and response plan for healthcare facilities. *Infect Control Hosp Epidemiol.* 2004; 25:1020-5.

70. Centers for Disease Control and Prevention. Supplement C: preparedness and response in healthcare facilities, 8 January 2004. Available at: http://www.cdc.gov/ncidod/sars/guidance/C/pdf/c.pdf. Accessed June 15, 2005.

71. Peng PW, Wong DT, Bevan D, Gardam M. Infection control and anesthesia: lessons learned from the Toronto SARS outbreak. *Can J Anesth.* 2003; 50:989-97.

72. McInnes K, Safian L. Keeping SARS out: an education program for SARS screeners in one Ontario hospital. *J Nurses Staff Dev.* 2005; 21:73-8.

73. Dwosh HA, Hong HH, Austgarden D, Herman S, Schabas R. Identification and containment of an outbreak of SARS in a community hospital. *CMAJ.* 2003; 168:1415-20.

APPENDIX 1: FIGURE AND TABLES

Figure. **Geographic Areas Most Affected by SARS: Summary of Probable Cases with Onset of Illness from 1 November 2002 to 31 July 2003**[3]

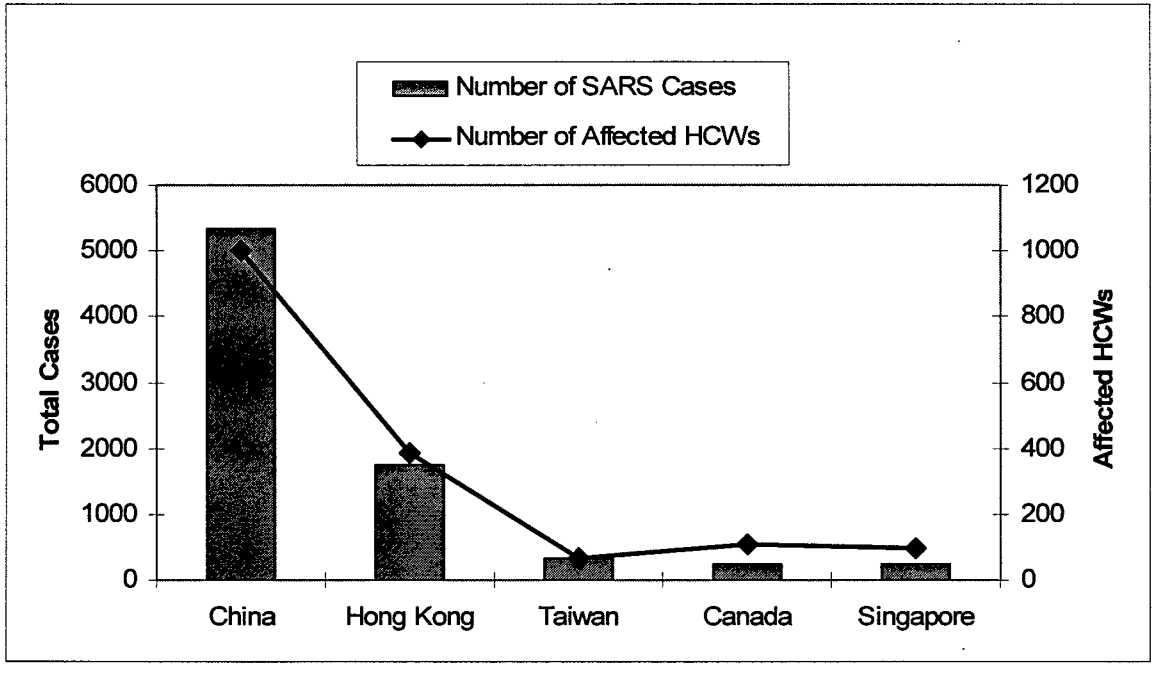

Table 1. **Risk Factors Associated with Transmission of SARS from Patient to Healthcare Worker***

Author (Reference)	Location	Study Design	Risk Factor	Result	Quality Rating†	
					Internal Validity	External Validity
Loeb et al (21)	Toronto	Retrospective Cohort		Unadjusted RR (95% CI)	Fair	Good
			Intubation	4.20 (1.58 to 11.14)		
			Suctioning before intubation	4.20 (1.58 to 11.14)		
			Manipulation of oxygen mask	9.00 (1.25 to 64.89)		
Fowler et al (22)	Toronto	Retrospective Cohort		Unadjusted RR (95% CI)	Poor	Poor
			HCW involved with intubation	13.29 (2.99 to 59.04)		
			Nurse assisting with intubation	21.38 (4.89 to 93.37)		
			Physician performing intubation	3.82 (0.23 to 62.24)		
			Caring for patient receiving NPPV	2.33 (0.25 to 21.76)		
			Caring for patient receiving HFO	0.74 (0.11 to 4.92)		
Scales et al (45)	Toronto	Retrospective Cohort		Unadjusted OR (95% CI)	Fair	Good
			HCW spending ≥31 min in patient's room	12.9 (1.27 to 131)		
			HCW spending >4 hours in patient's room	24.0 (1.85 to 311)		
			Caring for patient receiving NPPV (≥31 min)	105 (3 to 3,035)		
Teleman et al (46)	Singapore	Case-Control		Adjusted OR (95% CI)[1]	Fair	Good
			Contact with respiratory secretions	21.8 (1.7 to 274.8)		
Lau et al (47)	Hong Kong	Matched Case-Control		Adjusted OR (95% CI)[2]	Fair	Good
			Perceived inadequacy of PPE supply	4.27 (1.66 to 12.54)		
			SARS infection control training (<2 hrs or none)	13.6 (1.24 to 27.50)		
			Inconsistent use of more than one type of PPE when having direct contact with a SARS patient	5.06 (1.91 to 598.92)		

* CI = Confidence Interval; HCW = Healthcare Worker; HFO = High-Frequency Oscillatory; NNPV = Noninvasive Positive-Pressure Ventilation; OR = Odds Ratio; PPE = Personal Protective Equipment; RR = Relative Risk.

[1] Forward logistic regression analysis including gender, ethnic group, N95 masks, gloves, gowns, handwashing, and contact with respiratory secretions.

[2] Forward stepwise logistic regression including inconsistent use of at least 1 type of PPE when having contact with SARS patients, with "patients in general," when there was "no patient contact," when SARS infection control training was <2 hours, when the respondent reported not understanding SARS infection control procedures, when at least 1 piece of PPE was perceived to be in inadequate supply, and hand hygiene was inconsistent when there was no patient contact.

† Definitions of quality ratings. Good: Well designed, conducted and reported studies involving HCWs in hospital setting. Fair: Strength of the evidence is limited by mild to moderate potential for selection bias, measurement bias, or confounding. Poor: Strength of the evidence is negated by moderate to high potential for selection bias, measurement bias, or confounding.

Table 2. **Protective Factors Associated with Transmission of SARS from Patient to Healthcare Worker ***

Author (Reference)	Location	Study Design	Protective Factor	Result	Quality Rating†	
					Internal Validity	External Validity
Loeb et al (21)	Toronto	Retrospective Cohort		Unadjusted RR (95% CI)	Fair	Good
			N95 or surgical mask	0.23 (0.07 to 0.78)		
			N95 (vs. no mask)	0.22 (0.05 to 0.93)		
			Surgical mask (vs. no mask)	0.45 (0.07 to 2.71)		
			N95 vs. surgical mask	0.50 (0.06 to 4.23)		
Scales et al (45)	Toronto	Retrospective Cohort		Unadjusted OR (95% CI)	Fair	Good
			Use of gloves during patient contact	0.08 (0.01 to 1.11)		
Teleman et al (46)	Singapore	Case-Control		Adjusted OR (95% CI)[1]	Fair	Good
			N95 mask	0.1 (0.02 to 0.9)		
			Handwashing after each patient	0.07 (0.008 to 0.7)		
Seto et al (50)	Hong Kong	Case-Control		Adjusted OR (95% CI)[2]	Fair	Good
			Mask (N95, surgical, or paper)	0.08 (0.02 to 0.33)[3]		
			Handwashing	0.2 (0.05 to 1)[3]		

* CI = Confidence Interval; OR = Odds Ratio; RR = Relative Risk.

[1] Forward logistic regression analysis including gender, ethnic group, N95 masks, gloves, gowns, handwashing, and contact with respiratory secretions.

[2] Forward stepwise logistic regression including use of masks, gowns, gloves, and handwashing.

[3] Reciprocal value of reported protective measure.

† Definitions of quality ratings. Good: Well designed, conducted and reported studies involving HCWs in hospital setting. Fair: Strength of the evidence is limited by mild to moderate potential for selection bias, measurement bias, or confounding. Poor: Strength of the evidence is negated by moderate to high potential for selection bias, measurement bias, or confounding.

APPENDIX 2: EVIDENCE TABLES

1. Citation	2. Study question and research design	3. Source population	4. Study population (descriptive: demographics, eligibility criteria) and how chosen (volunteers, recruitment, tertiary care clinics, population-based, etc)	5. Initial comparability of groups (i.e., randomization or group composition; concealment of allocation)	6. Drop outs (no endpoint data), lack of adherence, cross-overs (other terms: attrition; loss to follow-up)	7. Potential for selection bias (grade + to +++, and explain)	8. Measurement (of exposure/ intervention; outcomes; potential confounders): reliability and validity of measurement instruments; how measurements were performed; include blinding if needed
Loeb M et al. SARS among critical care nurses, Toronto. Emerg Inf Dis. 2004; 10:251-5.	- Q: Hypothesized that patient care activities that increase exposure HCWs to respiratory droplets are associated with an increased risk of SARS transmission and use of masks is protective. - Design: Retrospective cohort.	- 43 nurses who cared for 3 probable SARS patients (subsequently laboratory confirmed) on two critical care units in a Toronto hospital from March 8-21, 2003.	- 32 nurses who entered a SARS patient's room at least once; 11 nurses who worked on the critical care units during this time had not entered the room of a SARS patient and were not included in the analysis. - 8 nurses were infected with SARS (4 probable and 4 suspected) (Health Canada = WHO definition); all laboratory confirmed cases by serology. - All cohort HCWs were female nurses; mean age 41 years (range 27-65); 2 with previous history of respiratory illness (1 with asthma, 1 with bronchitis); no other demographic or background data provided.	- Not able to compare groups with information provided in article.	- None.	- Potential for selection bias is assessed as low to moderate due to the lack of demographic data necessary to assess comparability of groups; the specific definition of the cohort and the use of serology to confirm the SARS diagnosis in both the nurses and the 3 source patients is a moderating factor in this rating.	- Cohort demographic data collected (age, sex, medical history, smoking, and use of immunosuppressive medications. - Trained research nurses abstracted data from source patient charts as to type and duration of patient care activities performed by the nurses, matched to their signature; also recorded the types of PPE and the duration and frequency of use from the charts; nurses interviewed about the specific care provided; information provided by the nurses was corroborated whenever possible by data from the charts. - Data on 33 patient care activities were collected.

9. Potential for measurement bias (grade + to +++, explain)	10. Potential confounders (name what they are and how each was controlled; i.e., by randomization, restriction, statistical adjustment, stratification, etc)	11. Potential for confounding (grade + to +++, explain)	12. Analysis (intention to treat if applicable, other adjustment, etc)	13. Results: magnitude and direction (point estimate); random error/precision (confidence interval); statistical significance	14. Clinical/public health importance of the result (explain) for the target population	15. Overall judgment of internal validity (good, fair, poor – explain)	16. External validity: applicability of findings to other populations beyond the target population	17. Comments and your overall statement of the info from the study (include consistency w/ other studies if you can)
- Potential for measurement bias is assessed as low based on the use of patient charts to corroborate nurses' recall.	- Potential confounders include: frequency and duration of exposure to SARS patient; actual viral load shed by individual SARS patients (unmeasured) during period of nurse care; actual and proper use of PPE by critical care nurses during patient care; potential for community acquired SARS from an unrecognized contact; age of HCW; pre-existing health of HCW.	- Potential for confounding is assessed as moderate.	- No multivariate analysis performed.	- Intubation: RR 4.20 (95% CI 1.58 to 11.14); suctioning before intubation RR 4.20 (1.58 to 11.14); manipulation of oxygen mask RR 9.00 (1.25 to 64.89); all other patient care activities were not statistically significant. - N95 mask or surgical mask (consistent use vs. inconsistent use) RR 0.23 (0.07 to 0.78); N95 mask (mask vs. no mask) RR 0.22 (0.05 to 0.93); N95 vs. surgical mask RR 0.50 (0.06 to 4.23).	- Aerosol generating procedures (intubation, suctioning, and oxygen mask manipulation) increase the risk of SARS transmission to HCWs assisting or performing care; the consistent use of s N95 mask (or any consistent use of a mask) provides significant protection from SARS transmission.	- Internal validity is assessed as fair; while the relative risk for many patient care activities were actually examined, only the originally hypothesized activities proved to be significant.	- External validity is assessed as good, due to the specific nature of the occupational group to which the study results would be generalized to.	- Findings are consistent with results from other studies; exposure to aerosol generating procedures increased the risk of SARS transmission; lack of transmission to HCW who had not entered a SARS patient's room implicates either droplet or limited aerosol generation as a means of transmission to HCWs; environmental transmission (i.e., contact through gown) not implicated.

- Fowler RA et al. Transmission of severe acute respiratory syndrome during intubation and mechanical ventilation. Am J Respir Crit Care Med. 2004; 169:1198-1202.	1. Citation
- Q: To determine whether specific ventilatory strategies were associated with an increased risk of SARS transmission from patient to HCW. - Design: Retrospective cohort.	2. Study question and research design
- 122 HCWs exposed to 7 SARS patients (diagnosis not defined; laboratory confirmation not discussed) in a hospital ICU in Toronto from April 1-22, 2003.	3. Source population
- 76 HCWs having any involvement with intubation of 6 SARS patients in a hospital ICU in Toronto from April 1-22, 2003. - 10 HCWs developed probable SARS (source of case definition not defined); 9 HCWs laboratory confirmed by PCR or serology; 1 HCW did not have either test performed. - All patients treated in negative pressure isolation rooms; all HCWs wore gloves, gowns, N95/PCM2000 masks, and hairnets; eye or face shields were variably used.	4. Study population (descriptive: demographics, eligibility criteria) and how chosen (volunteers, recruitment, tertiary care clinics, population-based, etc)
- The mean age of HCWs with SARS was 35.1 $\pm$ 6.5 years and 36.2 $\pm$ 4.7 years among those without SARS ($p = 0.7$); no other demographic or background information provided. - Not able to compare groups with information provided in article.	5. Initial comparability of groups (i.e., randomization or group composition; concealment of allocation)
- None mentioned.	6. Drop outs (no endpoint data), lack of adherence, cross-overs (other terms: attrition; loss to follow-up)
- Potential for selection bias is assessed as moderate due to the lack of demographic data necessary to assess comparability of groups; also problematic was the lack of laboratory confirmation of the 7 SARS patients; however the cohort of HCWs performing the specific procedures was fairly well defined and serology was used to confirm the SARS diagnosis in the HCWs (9 out of 10).	7. Potential for selection bias (grade + to +++, and explain)
- No mention made of how information was gathered. - Restricted analysis to 3 respiratory practices: physicians who performed intubation or nurses who assisted (vs. HCWs who treated SARS patients, but were not present for intubation); nurses who cared for SARS patients receiving noninvasive positive-pressure ventilation (NPPV); nurses who cared for patients with high-frequency oscillatory (HFO) ventilation (last two compared with nurses who cared for SARS patients treated with conventional ventilation).	8. Measurement (of exposure/ intervention; outcomes; potential confounders); reliability and validity of measurement instruments; how measurements were performed; include blinding if needed

9. Potential for measurement bias (grade + to +++, explain)	10. Potential confounders (name what they are and how each was controlled: i.e., by randomization, restriction, statistical adjustment, stratification, etc)	11. Potential for confounding (grade + to +++, explain)	12. Analysis (intention to treat if applicable, other adjustment, etc)	13. Results: magnitude and direction (point estimate); random error/precision (confidence interval); statistical significance	14. Clinical/public health importance of the result (explain) for the target population	15. Overall judgment of internal validity (good, fair, poor – explain)	16. External validity: applicability of findings to other populations beyond the target population	17. Comments and your overall statement of the info from the study (include consistency w/ other studies if you can)
- Potential for measurement bias is assessed as moderate to high; while the outcome measures were fairly well spelled out, the lack of discussion on how the information was gathered or verified down grades the validity of the data.	- Potential confounders include: frequency and duration of exposure to SARS patient; actual viral load shed by individual SARS patients (unmeasured) during period of care; actual and proper use of PPE by HCWs during patient care; potential for community acquired SARS from an unrecognized contact; age of HCW; pre-existing health of HCW.	- Potential for confounding is assessed as moderate.	- No multivariate analysis performed.	- HCW involved with intubation RR 13.29 (95% CI 2.99 to 59.04); nurses involved with intubation RR 21.28 (4.89 to 93.37); physicians performing intubation 3.82 (0.23 to 62.24); caring for patient treated with NPPV RR 2.33 (0.25 to 21.76); caring for patient treated with HFO RR 0.74 (0.11 to 4.92).	- Nurses assisting with endotracheal intubation are at increased risk for contracting SARS; physicians who perform intubation also appear to be at increased risk, but this association did not reach statistical significance.	- Internal validity is assessed as fair to poor due to the inadequate reporting of how the data was gathered and the lack of cohort characteristics for assessing comparability.	- External validity is assessed as fair to poor (in keeping with the equivalent assessment of internal validity).	- While the findings from this study are affected by the poor internal validity, they are consistent with other studies; exposure to aerosol generating procedures increased the risk of SARS transmission to HCWs.

1. Citation	- Scales DC et al. Illness in intensive care staff after brief exposure to severe acute respiratory syndrome. Emerg Inf Dis. 2003; 10:1205-10.
2. Study question and research design	- Q: Not explicitly stated in article; what factors are associated with SARS transmission after brief unexpected exposure to a patient with undiagnosed SARS (later laboratory confirmed). - Design: Retrospective cohort.
3. Source population	- 69 HCW considered to be at high risk for developing SARS due to exposure to 1 SARS patient from 23-24 March 2003 in a Toronto hospital ICU; HCWs either entered the patient's room or had been in the ICU >4 hours during the patients 30.75 hour stay; HCWs quarantined.
4. Study population (descriptive; demographics, eligibility criteria) and how chosen (volunteers, recruitment, tertiary care clinics, population-based, etc)	- Unit of analysis was 31 HCWs who entered the index patient's room. - SARS developed in 6 HCWs (5 probable, 1 suspected; WHO SARS case definitions) who entered the patient's room. - SARS developed in 1 HCW who had not entered the index patient's room, but who was in the larger cohort of 69 HCWs quarantined. - HCWs should have been taking precautions for suspected methicillin-resistant *Staphylococcus aureus.*
5. Initial comparability of groups (i.e., randomization or group composition; concealment of allocation)	- No demographic information provided; the only background information provided was that one HCW in the cohort had a history of type II diabetes mellitus, while all other HCWs were previously healthy. - Not able to compare groups with information provided in article.
6. Drop outs (no endpoint data), lack of adherence, cross-overs (other terms: attrition; loss to follow-up)	- 63 of the 69 HCWs were interviewed, 5 declined and 1 could not be contacted. - SARS did not develop in any HCWs not quarantined.
7. Potential for selection bias (grade + to +++, and explain)	- Potential for selection bias is assessed as moderate due to the lack of demographic data necessary to assess comparability of groups; also contributing to this rating were the arbitrary definition of the quarantined cohort (on the ICU >4 hours) and the lack of laboratory confirmation of SARS in these 7 HCWs.
8. Measurement (of exposure/ intervention; outcomes; potential confounders); reliability and validity of measurement instruments; how measurements were performed; include blinding if needed	- HCWs were interviewed by two researchers using a structured questionnaire; information collected included: personal demographic and health information, length of exposure, exposure proximity, procedures performed, and infection control precautions used (but did not include handwashing).

9. Potential for measurement bias (grade + to +++, explain)	10. Potential confounders (name what they are and how each was controlled: i.e., by randomization, restriction, statistical adjustment, stratification, etc)	11. Potential for confounding (grade + to +++, explain)	12. Analysis (intention to treat if applicable, other adjustment, etc)	13. Results: magnitude and direction (point estimate); random error/precision (confidence interval); statistical significance	14. Clinical/public health importance of the result (explain) for the target population	15. Overall judgment of internal validity (good, fair, poor – explain)	16. External validity: applicability of findings to other populations beyond the target population	17. Comments and your overall statement of the info from the study (include consistency w/ other studies if you can)
- Potential for measurement bias is assessed as low based on the short time of exposure to only one source patient and the fact that the information was collected shortly after the exposure.								
	- Potential confounders include: actual viral load shed by individual SARS source patients (unmeasured) during period of care; actual and proper use of PPE by HCWs during patient care; potential for community acquired SARS from an unrecognized contact; age of HCW; pre-existing health of HCW.							
- Potential for confounding is assessed as moderate.								
			- Classification and regression tree methods were used to identify predictors of developing SARS; no multivariate analysis performed.					
				- Of HCWs who entered the patient's room: ≥31 min OR 12.9 (95% CI 1.27 to 131); ≥4 hours OR 24.0 (1.85 to 311); present in room for ≥31 min during administration of NPPV OR 105 (3 to 3,035); use of gloves when having contact with SARS patient's mucous membranes or respiratory secretions OR 0.08 (0.01 to 1.11). SARS developed in 1 HCW despite wearing N95 mask, gloves, and gown (note: no eye protection; not fit-tested for mask).				
					- Results suggest that the greatest risk for SARS transmission occurs in those HCWs with prolonged exposure or direct contact with a SARS infected patient. The fact that 1 HCW acquired SARS without entering the patient's room suggests transmission by indirect contact with contaminated objects.			
						- Internal validity is assessed as fair due to low potential for measurement bias, and moderate potential for selection bias and confounding.		
							- External validity is assessed as good, due to the specific nature of the occupational group to which the study results would be generalized to.	
								- Findings are consistent with results from other studies; proximity and duration of contact with a SARS patient are associated with risk for transmission to HCWs;

1. Citation	- Lau JTF et al. SARS Transmission among hospital workers in Hong Kong. Emerg Inf Dis. 2004; 10:280-6.
2. Study question and research design	- Q: What factors were associated with breakthrough transmission of the SARS virus among hospital workers infected in hospital settings? - Design: 1:2 Matched case-control.
3. Source population	- HCWs who cared for 453 laboratory confirmed SARS patients in wards of a cluster of five hospitals in Hong Kong from March 28 to May 25, 2003.
4. Study population (descriptive: demographics, eligibility criteria) and how chosen (volunteers, recruitment, tertiary care clinics, population-based, etc)	- 72 HCWs (out of 77; 93.5%) with probable or suspected SARS (WHO case definitions; all subsequently laboratory confirmed); as all staff was required to use protective masks from March 12, 2003, these HCWs were presumed to have contracted the virus as a result of "breakthrough" transmission. - Each case matched to healthy HCW who had been working in the same job position, in the same ward, and in proximity with the case-patient. - No description of case or control groups other than aggregate totals of job category and where they were employed.
5. Initial comparability of groups (i.e., randomization or group composition; concealment of allocation)	- No demographic or background information provided.
6. Drop outs (no endpoint data), lack of adherence, cross-overs (other terms: attrition; loss to follow-up)	- None.
7. Potential for selection bias (grade + to +++, and explain)	- Potential for selection bias is assessed as moderate, based on the lack of demographic data to assess comparability of case and control groups, and the selection of the control group through a combination of nomination process by infected HCWs and an undefined random selection from the duty roster of the day before the case felt unwell, matching for job type.
8. Measurement (of exposure/ intervention; outcomes; potential confounders); reliability and validity of measurement instruments; how measurements were performed; include blinding if needed	- An infection control nurse administered a structured questionnaire to both groups; questions reviewed exposure (3 categories: direct exposure with SARS patient, contact with patients in general, no patient contact), social contact with others who were later found to be SARS cases, present during high risk procedures, wear of PPE (N95 or surgical mask, gloves, goggles, gowns, cap), problems with wear of PPE, perceived adequacy of PPE supply, and length of SARS infection control training.

9. Potential for measurement bias (grade + to +++, explain)	10. Potential confounders (name what they are and how each was controlled: i.e., by randomization, restriction, statistical adjustment, stratification, etc)	11. Potential for confounding (grade + to +++, explain)	12. Analysis (intention to treat if applicable, other adjustment, etc)	13. Results: magnitude and direction (point estimate); random error/precision (confidence interval); statistical significance	14. Clinical/public health importance of the result (explain) for the target population	15. Overall judgment of internal validity (good, fair, poor – explain)	16. External validity: applicability of findings to other populations beyond the target population	17. Comments and your overall statement of the info from the study (include consistency w/ other studies if you can)
- Potential for measurement bias is assessed as low to moderate; duration and number of potential interactions with individual SARS patients; potential for recall bias, and lack of verification of questionnaire data with patient charts were factors in assessment.	- Potential confounders include: differences in actual length of exposure to SARS patients between cases and control; actual viral load shed by individual SARS source patients (unmeasured) during period of care; actual and proper use of PPE by HCWs during patient care; age of HCW; pre-existing health of HCW. - Social contact with SARS patients taken into consideration.	- Potential for confounding is assessed as low to moderate.	- Rather broad study question led to the calculation of some 50 separate ORs. - Forward stepwise logistic regression.	- Adjusted OR: perceived inadequacy of PPE supply OR 4.27 (1.66 to 12.54); SARS infection control training <2 hrs of no training OR 13.6 (1.24 to 27.50); inconsistent use of more than one type of PPE when having direct contact with a SARS patient OR 5.06 (1.91 to 598.92); did not understand infection control measures OR 3.14 (1.35 to 7.73); no significant difference for those who performed high-risk procedures on SARS patients.	- In order to prevent transmission of SARS from patient to HCW, there must be sufficient time allotted for infection control training to ensure HCWs understand IC measures and how to utilize PPE; provide regular updates as situations warrant; must manage PPE supply to ensure adequacy/prevent perceptions of shortages	- Internal validity is assessed as fair to due to moderate potential for selection bias, measurement bias, and confounding in this study.	- External validity is assessed as good, due to the specific nature of the occupational group to which the study results would be generalized to.	- While definitive conclusions cannot be drawn based upon the risk factors identified as significant in this study, the findings are consistent with findings from other authors during the same time period and potentially present unique insight into the importance of infection control training.

1. Citation	- Teleman MD et al. Factors associated with transmission of severe acute respiratory syndrome among health-care workers in Singapore. Epidemiol Infect. 2004; 132:797-803.
2. Study question and research design	- Q: Risk and protective factors for nosocomial transmission of SARS in Tan Tock Seng Hospital, Singapore. - Design: Case-control.
3. Source population	- HCWs from SARS-affected wards who reported exposure (being within 1 meter) to 3 source patients with probable SARS (all 3 subsequently laboratory confirmed).
4. Study population (descriptive: demographics, eligibility criteria) and how chosen (volunteers, recruitment, tertiary care clinics, population-based, etc)	- Cases were HCWs admitted March 1-31, 2003; diagnosis based upon WHO criteria; all cases were subsequently laboratory confirmed by serology; 36 of 44 infected HCWs (82%) were recruited (6 were too ill to be interviewed and 2 died before they could be interviewed. - Controls were 50 HCWs working in the same wards as the cases, with history of exposure (being within 1 meter) but who did not develop SARS (size of HCW pool not defined). - Demographic data provided on gender, age (<30, ≥30), comorbid conditions, and ethnicity).
5. Initial comparability of groups (i.e., randomization or group composition; concealment of allocation)	- The two groups were fairly comparable, with the only significant difference being a higher Chinese ethnicity within the case group; the age of the control group was slightly older than the cases; the presence of comorbid conditions (not defined) was comparable between the case and control group (16.7% vs. 18.0%).
6. Drop outs (no endpoint data), lack of adherence, cross-overs (other terms: attrition; loss to follow-up)	- None.
7. Potential for selection bias (grade + to +++, and explain)	- The potential for selection bias is assessed as low to moderate, as the two groups were fairly comparable but the process for selecting controls from the pool of exposed HCWs was not described.
8. Measurement (of exposure/ intervention; outcomes; potential confounders); reliability and validity of measurement instruments; how measurements were performed; include blinding if needed	- Telephone interviews by staff experienced in epidemiological investigation using a closed questionnaire; information collected included demographic data, occupation, medical history within previous 5 years, and history of performing procedures with transmission risk; also questioned on compliance with PPE recommendations; no information provided as to if interviewers were blinded.

9. Potential for measurement bias (grade + to +++, explain)	10. Potential confounders (name what they are and how each was controlled: i.e., by randomization, restriction, statistical adjustment, stratification, etc)	11. Potential for confounding (grade + to +++, explain)	12. Analysis (intention to treat if applicable, other adjustment, etc)	13. Results: magnitude and direction (point estimate), random error/precision (confidence interval); statistical significance	14. Clinical/public health importance of the result (explain) for the target population	15. Overall judgment of internal validity (good, fair, poor – explain)	16. External validity: applicability of findings to other populations beyond the target population	17. Comments and your overall statement of the info from the study (include consistency w/ other studies if you can)
- Potential for measurement bias is assessed as low to moderate; while the outcome measures were fairly well spelled out, the length of time covered and recall bias played a factor in down grading this rating.	- Potential confounders include: frequency and duration of exposure to SARS patient; actual viral load shed by individual SARS patients (unmeasured) during period of care; actual and proper use of PPE by HCWs during patient care; potential for community acquired SARS from an unrecognized contact.	- Potential for confounding is assessed as moderate.	- Forward logistic regression analysis.	- Univariate analysis: contact with respiratory secretions OR 6.9 (95% CI 1.4 to 34.6); handwashing after each patient OR 0.06 (0.007 to 0.5); wearing N95 masks when attending to patients OR 0.1 (0.03 to 0.4). - Multivariate analysis: contact with respiratory secretions adjusted OR 21.8 (1.7 to 274.8); handwashing adjusted OR 0.07 (0.008 to 0.7); controlling for gender, ethnicity, N95 mask, gloves, gown.	- Contact with respiratory secretions from SARS patients is associated with a significant risk of SARS transmission to HCWs; handwashing after attending patients is strongly protective against transmission of SARS.	- Internal validity is assessed as fair; while selection bias and measurement bias were fairly well controlled, the uncertainty over the influence of confounding factors potentially affects the results.	- External validity is assessed as good, due to the specific nature of the occupational group to which the study results would be generalized to.	- Findings are consistent with results from other studies; provides evidence for contact, both direct and indirect, with respiratory secretions or body fluids, as a major risk factor for transmission in the hospital setting; personal protective measures against droplet spread and contact are effective against SARS transmission.

- Seto WH et al. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). Lancet. 2003; 316:1519-20.	1. Citation
- Q: Assess the effectiveness of droplet precautions for prevention of nosocomial transmission of SARS from patients to HCWs. - Design: Case-control.	2. Study question and research design
- HCWs from 5 Hong Kong hospitals exposed to (coming within 3 feet) 11 SARS patients; a sixth hospital was excluded due to a large outbreak involving a drug nebulizer used on an index patient for >10 days (reason – droplet precautions not effective for aerosol-generating procedures).	3. Source population
- 13 HCWs acquired SARS (own case definition; infected HCWs were those who acquired SARS 2-7 days after exposure, with no exposure to cases outside the hospital; 1 HCW had no exposure to any admitted SARS patient and was classified as a community acquired case); all index patients and HCWs with SARS, except one, were laboratory confirmed. - 241 non-infected controls; 356 questionnaires returned (85% of staff on roster for affected wards), out of which 102 were excluded due to no contact with SARS patient;	4. Study population (descriptive: demographics, eligibility criteria) and how chosen (volunteers, recruitment, tertiary care clinics, population-based, etc)
- Limited demographic data reported (gender, occupation, and unit). - Not able to compare groups with information provided in article.	5. Initial comparability of groups (i.e., randomization or group composition, concealment of allocation)
- Information on use of PPE collected from all 13 infected HCWs; questionnaires not returned from 15% of non-infected HCWs (~60).	6. Drop outs (no endpoint data), lack of adherence, cross-overs (other terms: attrition; loss to follow-up)
- Potential for selection bias is assessed as low to moderate due to the lack of demographic data necessary to assess comparability of groups; the specific definition of the cohort and the use of serology to confirm the SARS diagnosis in both the 13 HCWs and the 11 index patients is a moderating factor in this rating.	7. Potential for selection bias (grade + to +++, and explain)
- Questionnaire used to collect data from infected and non-infected staff on the current roster in the clinical wards providing care for the index patients with SARS; those who had cared for SARS patients were asked about use of masks (paper, surgical, or N95), gloves, gowns, and handwashing; responses were yes, most of the time, or no; survey conducted March 15-24, 2003.	8. Measurement (of exposure/ intervention; outcomes; potential confounders); reliability and validity of measurement instruments; how measurements were performed; include blinding if needed

9. Potential for measurement bias (grade + to +++, explain)	10. Potential confounders (name what they are and how each was controlled: i.e., by randomization, restriction, statistical adjustment, stratification, etc)	11. Potential for confounding (grade + to +++, explain)	12. Analysis (intention to treat if applicable, other adjustment, etc)	13. Results: magnitude and direction (point estimate); random error/precision (confidence interval); statistical significance	14. Clinical/public health importance of the result (explain) for the target population	15. Overall judgment of internal validity (good, fair, poor – explain)	16. External validity: applicability of findings to other populations beyond the target population	17. Comments and your overall statement of the info from the study (include consistency w/ other studies if you can)
- Potential for measurement bias is assessed as low to moderate; while outcome measures were fairly well spelled out, there was a likelihood of multiple exposures over an undefined period of time and there was no corroboration of HCW recall with patient charts.	- Potential confounders include: frequency and duration of exposure to SARS patient; actual viral load shed by individual SARS patients (unmeasured) during period of care; actual and proper use of PPE by HCWs during patient care; potential for community acquired SARS from an unrecognized contact; age of HCW; pre-existing health of HCW.	- Potential for confounding is assessed as moderate.	- Forward stepwise logistic regression of four factors; "yes" and "most of the time" were grouped together in the analysis.	The OR for HCWs who used a mask of not getting infected (protective measure) was 13 (95% CI 3 to 60), controlling for the other three variables measured; protective OR for handwashing was 5 (1 to 19), controlling for the other three variables; staff who wore surgical and N95 masks were significantly associated with non-infection, but this was not seen with paper masks; no staff who used all four measures became infected.	= Precautions against droplet and contact are adequate for prevention of nosocomial SARS, where no aerosolizations are expected; surgical and N95 masks were both effective in significantly reducing the risk of infection.	- Internal validity is assessed as fair; while the 4 variables were simple and measured in a straight forward manner, the failure to account for demographic differences contributed to the potential for confounding.	- External validity is assessed as good, due to the specific nature of the occupational group to which the study results would be generalized to.	- Findings are consistent with results from other studies; the protective role of the mask suggests that in hospital settings, infection is transmitted by droplets.

APPENDIX 3: PROPER DONNING AND REMOVAL OF PPE

Sequence for Donning and Removing PPE (CDC)[59]

Donning:
The type of PPE used will vary based on the level of precautions required; e.g., Standard and Contact, Droplet or Airborne Infection Isolation.

2. Gown
   - Fully cover torso from neck to knees, arms to end of wrists, and wrap around the back
   - Fasten in back of neck and waist
3. Mask or Respirator
   - Secure ties or elastic bands at middle of head and neck
   - Fit flexible band to nose bridge
   - Fit snug to face and below chin
   - Fit-check respirator
4. Goggles or Face Shield
   - Place over face and eyes and adjust to fit
5. Gloves
   - Extend to cover wrist of isolation gown

Safe Work Practices:
1. Keep hands away from face
2. Limit surfaces touched
3. Change gloves when torn or heavily contaminated
4. Perform hand hygiene

Removing:
Except for respirator, remove PPE at doorway or in anteroom. Remove respirator after leaving patient room and closing door.

1. Gloves
   - Outside of gloves is contaminated!
   - Grasp outside of glove with opposite gloved hand; peel off
   - Hold removed glove in gloved hand
   - Slide fingers of ungloved hand under remaining glove at wrist
   - Peel glove off over first glove
   - Discard gloves in waste container
2. Goggles or Face Shield
   - Outside of goggles or face shield is contaminated!
   - To remove, handle by head band or ear pieces
   - Place in designated receptacle for reprocessing or in waste container
3. Gown
   - Gown front and sleeves are contaminated!

- Unfasten ties
- Pull away from neck and shoulders, touching inside of gown only
- Turn gown inside out
- Fold or roll into a bundle and discard

4. Mask or Respirator
   - Front of mask/respirator is contaminated--DO NOT TOUCH!
   - Grasp bottom, then top ties or elastic and remove
   - Discard in waste container
5. Perform hand hygiene immediately after removing all PPE